[Proc. Roy. Soc. Victoria, 43 (N.S.), Pt. II, 1931.]

Art. IX.—*The Age, Distribution and Petrological Characters of the Granites of Eastern Australia.*

By Professor ERNEST W. SKEATS, D.Sc. A.R.C.Sc.. F.G.S.
(Department of Geology, University of Melbourne).

(With Plate VI).

[Read 14th August, 1930; issued separately 15th January, 1931.]

Introduction.

The collection of material for this paper was made for the purposes of a discussion, of which the author was leader, at the Brisbane meeting of the Australasian Association (now Australian and New Zealand Association) for the Advancement of Science, in May, 1930.

In many respects Australia may be considered as consisting of two parts or units. The Western part or unit includes West Australia, South Australia, Central Australia and North Australia, and consists largely of an exposed basement of Pre-Cambrian rocks riddled with ancient basic and acid intrusions, with a minor development of generally more or less flat-lying younger sediments resting on it.

Eastern Australia, comprising Tasmania, Victoria, New South Wales and Queensland, has in great measure a distinct geological history. In successive geological periods marine sediments have been added to the old Pre-Cambrian basement, which now is only exposed in the western part of the block. The Palæozoic marine sediments have been closely folded and even the Mesozoic sediments suffered minor folding before the close of the period. Associated probably with late stages in the various fold movements, intrusions of granitic and other igneous rocks have invaded these sediments and are now exposed at the surface over wide areas. This paper is concerned solely with the granitic intrusions of the eastern unit of the continent, with their geographical distribution, their ages, and to some extent their petrological characters.

The subject is so comprehensive that little progress could have been made without the assistance from geological colleagues in the States of Eastern Australia. I have received from Mr. P. B. Nye, B.M.E., Government geologist of Tasmania, a map of the distribution of the granites of Tasmania and a useful discussion of their age and characters. In Victoria Mr. D. J. Mahony, M.Sc., has supplied me with a statement on Victorian granites and Mr. H. B. Hauser, M.Sc., has helped me with the literature generally. In New South Wales Dr. W. R. Browne's presidential address to the Linnean Society of New South Wales, 1929, has supplied a wealth of information with regard to New South Wales occurrences and this he has supplemented in correspondence. In Queensland Mr. Dunstan has provided me with a map showing the distribution of the Queensland granites, Professor Richards has given information by letter, and Dr. Bryan's presidential address to the Royal Society of Queensland in 1925 has provided valuable information on Queensland granites. Dr. Browne's and Dr. Bryan's papers provide the bulk of the references to literature. The remainder are in Geological Survey and Royal Society publications of the various States.

In attempting to summarize the information available, to supplement it, and to evaluate the evidence for the ages of the various granites of Eastern Australia, I have been led to realize how much of the information is based on analogy, on certain mineral resemblances or on correlation with periods of what are believed to be mountain-making movements, and how little of it is based on definite stratigraphical evidence.

In setting out the information, it is proposed to describe the granitic rocks in order of age, commencing with the Pre-Cambrian, and under each period to deal summarily with their mineral characters and their distribution in the States of Tasmania, Victoria, New South Wales and Queensland. Proceeding in this way it is hoped that material for tentative generalizations may emerge, and in any case, correlation may be facilitated and the strength or weakness of the evidence in particular cases may be more clearly realized.

As a preliminary it must be stated that the evidence of age of many granites is very indefinite. In particular cases it may amount to no more than that a granite is intrusive into Pre-Cambrian rocks and is older than the Pleistocene. In such cases the reference of a granite to a particular period of intrusion must rest upon evidence of an indirect, inferential and usually uncertain character. In showing the general distribution of the granites of Eastern Australia upon a map in which tentative or positive ages are assigned by colouring or shading, it is recognized that the only really safe reference is to describe the granites as intrusive into Pre-Cambrian, into Ordovician, Silurian or Permo-Carboniferous, as the case may be. (See Plate VI).

Pre-Cambrian Granites.

TASMANIA.

The Pre-Cambrian rocks of Tasmania include some altered basic igneous rocks but so far as is known no granites. Small intrusions of pegmatites into Pre-Cambrian rocks near Ulverstone, however, have been recognized.

VICTORIA.

The metamorphic rocks in N.E. Victoria, for a time referred to the Pre-Cambrian, are now believed to be Upper Ordovician sediments metamorphosed by and associated with younger gneisses and granites.

In Western Victoria granites, pegmatites and gneissic rocks occur among schists in the basin of the Glenelg River. Their age is not known with certainty, but as they show some resemblance to Pre-Cambrian rocks in South Australia they are regarded as probably of Pre-Cambrian age. The Dergholm granite in the Western District is an acid variety similar to the granites of the Murray Bridge district, and may be Pre-Cambrian. In the Bushey Creek district, south of Glen Thompson, a small triangular area of schists and other metamorphic rocks, including some granites, junctions sharply with normal folded sediments and with diabases and cherts to the north. These latter types are, in the absence of fossils, on lithological grounds correlated with the Lower Ordovician and Cambrian (Heathcotian) respectively. If this reference is correct the metamorphic rocks to the south and the granite types associated with them are presumably of Pre-Cambrian age.

NEW SOUTH WALES.

In Western New South Wales, in the Barrier Ranges, Lower Cambrian or Proterozoic sediments, including tillites, rest unconformably on a thick series of schists and gneisses of Pre-Cambrian age—known as the Willyama series. With them are associated acid granite gneisses and later biotite granite gneisses as concordant intrusions into the metamorphosed sediments. The rocks are commonly foliated. The foliated concordant types are regarded as deep-seated or abyssal injections. Later than these is a massive, rather acid type, with pegmatite, the Mundi Mundi granite. It occurs as sills or intrusive sheets. As no igneous rocks penetrate the Proterozoic(?) tillites it is inferred that both the massive and the foliated intrusions are of Pre-Cambrian age.

QUEENSLAND.

"Associated with the very metamorphosed Pre-Cambrian series of the Cloncurry district, with the supposedly Pre-Cambrian series of the Einasleigh district, and with several of those other very old series which may be Pre-Cambrian . . . there are found granite rocks of a very old facies" (Bryan). These older granites of the Einasleigh, Croydon and Cloncurry districts are largely due to "lit-par-lit" injection. While the bulk of these older granites is gneissic, coarse granites and intrusive pegmatite dykes also occur. The Pre-Cambrian age of the metamorphosed sediments of the Cloncurry district is inferred by reason of the fact that unaltered and relatively flat-lying fossiliferous Lower or Middle Cambrian sediments occur at the Templeton Range a few miles to the West. Since these Cambrian rocks are not penetrated by granite intrusions the Pre-Cambrian age of the gneissic granites is probable.

To the west of Cairns, as in the Mareeba district, are granite gneisses which are believed to be of Lower Palæozoic or older age.

Cambrian and Cambro-Ordovician Granites.

TASMANIA.

The proved Cambrian sediments of Tasmania have no associated intrusive rocks.

Among the series described as Cambro-Ordovician in Tasmania are the porphyroid suite of igneous rocks interbedded with and also intrusive into the Cambro-Ordovician series, especially those associated with and overlying the Dundas series. They are overlain by the basal series (West Coast Range Conglomerates) of the Silurian system which contain pebbles of the porphyroid rock types. They are thus pre-basal-Silurian. Although not foliated they have been subjected to stresses resulting in strain and mineral re-constitution from which the Devonian granites are free.

The granitic rocks occur in the western, north-western and north-central divisions of the State; their areal extent is small but they are associated with other igneous rocks of the same suite which occupy a greater area. The granites are known from a few localities only, e.g., Mt. Farrel, where granite and syenite occur. The greater part of the plutonic rocks is a syenite with quartz in some specimens. At Dove River (and Bond Peak) an acid red granite and a granophyre occur. In the Low Rocky Point district long dykes of extremely coarse grained to medium grained acid granite are intrusive into the Cambro-Ordovician series.

VICTORIA.

The Upper Cambrian (Heathcotian) rocks of the Heathcote district in central Victoria consist largely of basic lavas ("diabase") and ashes and interbedded cherts passing up into chocolate-coloured shales. At Heathcote the "diabase" series is intruded by a fine grained granodiorite or microgranite in which oligoclase, orthoclase, muscovite and a little biotite occur. It differs markedly from the Devonian granites and is believed to belong genetically to the Heathcotian "diabases" and to be a late acid differentiate from the basic magma. It is only known to intrude the "diabase and diabase ash." Many of the Ordovician sandstones of Victoria on microscopic examination are found to contain a fair quantity of felspar, presumably of granitic origin. One may therefore safely infer their derivation from fairly wide-spread pre-Ordovician granites now largely buried beneath younger rocks.

NEW SOUTH WALES.

Albitised lavas and tuffs are interbedded with Ordovician sediments at Forbes and in this district granophyric soda-aplite and a fine grained albite gneiss, both evidently intrusive, occur. Their exact relationships with the volcanic rocks are not known, but their richness in soda suggests that they may be co-magmatic and if so their reference to the Ordovician is justified.

QUEENSLAND.

Granitic rocks of this age are unknown in Queensland.

Lower Devonian(?) Granites.

TASMANIA.

Granites of post-Silurian age occur throughout Tasmania, but especially in the north-western, north-eastern, eastern and south-western parts. The largest areas are in the north-eastern and eastern districts, where they probably represent the outcropping portions of a batholith. The tin deposits of Tasmania are associated with these post-Silurian granites, while basic and ultra-basic intrusions are often associated with the granites, as slightly earlier intrusions.

The age of the granites is determined by the following evidence:—

1. They are intrusive into all rock formations up to and including the Silurian. They therefore are post-Silurian.
2. They are overlain by the basal beds of the Permo-Carboniferous and therefore are pre-Permo-Carboniferous.
3. The Older Palæozoic rocks have been eroded not only sufficiently to expose the granites but to form a peneplain before the Permo-Carboniferous beds were laid down. The granite intrusions thus occurred a considerable time before the Permo-Carboniferous.

These granites have usually been placed in the Lower Devonian and as such are placed here, but the evidence does not exclude the possibility of their being of Upper Devonian or even of Lower Carboniferous age. In the north-east district the normal rock type is porphyritic granodiorite approaching adamellite, but in the vicinity of the tin deposits the granite is usually finer, more even grained and contains muscovite, either primary or secondary. At Lisle and Golconda the rock is a non-porphyritic, fine grained biotite granite. In close proximity to the tin deposits, pegmatite, aplite and greisen occur. At Heemskirk, Meredith Range and Stanley River, pink granite, granite porphyry, aplite and pegmatite occur. In the Balfour district the granite is porphyritic and medium grained while at Moina it is a pink, even and medium grained rock.

VICTORIA.

The bulk of the granitic rocks of Victoria used to be regarded as probably of Lower Devonian age. For many of the occurrences the evidence was, and still is, unsatisfactory. The acid granite porphyry of Mt. Taylor near Bairnsdale is clearly pre-Upper Devonian, for flat-bedded sediments of that age rest upon it. Howitt described several granitic rocks and quartz-mica diorites in North Gippsland, especially in the Omeo and Ensay districts, as intruding the Silurian [Upper Ordovician]. Some of his papers were written before the term Ordovician was coined and all of them before the term was in current use in Australia. Some writers who have quoted Howitt's work have not realized that his Silurian rocks are Upper Ordovician in our present sense. Howitt refers, however, to certain granitic rocks as underlying the Snowy River Porphyries, which pass up into the Middle Devonian limestones. Such granites he referred to the commencement of the Lower Devonian and the reference seems to be justified. The general low dips, apart from local folding, of the Mid-Devonians of Buchan and Bindi and the absence of granitic rocks intrusive into them suggest that the granitic rocks of much of Eastern Victoria antedate the Mid-Devonian. The only area of Mid-Devonian sediments which is closely folded is near Tabberabbera, where a diorite-porphyrite may be intrusive into them, but its relations are not precisely settled. Many of the granitic and gneissic rocks of Eastern Victoria are clearly intrusive into Upper Ordovician sediments. We may conclude that in much of Eastern Victoria the granitic and gneissic rocks are post-Upper Ordovician and probably pre-Middle Devonian, but beyond that we cannot go with certainty. The question as to whether granitic intrusions followed the close of the Ordovician period or the close of the Silurian period deserves consideration.

The Silurian and Ordovician sediments are more completely developed and have been more closely studied in Victoria than in New South Wales or the other States. It is found that the strikes of the two series are sometimes discordant, suggesting unconformable relations and a period of earth movements between them. But the inliers of Upper Ordovician rocks north of Walhalla and in the Wood's Point district have similar strikes and dips to the adjoining Silurian sediments. The Ordovician sediments are generally, but not always, more closely folded than the Silurian sediments, but the graptolite content of the beds at the top of the Upper Ordovician and those at the base of the Silurian show such marked resemblances and so few differences that the time interval between them must have been small, and little or nothing of mountain-making movements could have occurred during this interval. Even if close folding of the mountain-making type could be demonstrated to occur in such a time interval, it would not prove that granitic intrusions accompanied it, for such intrusions, while common in these circumstances, are sometimes wanting. Tattam (Bull. 52, Geol. Surv. Vic., 1929), following an earlier view of Howitt, points out that the metamorphic belt of North-Eastern Victoria with its associated foliated gneisses and massive granites appears to constitute the axis of a big structural anticline or geanticline, on either flanks of which lie normal Upper Ordovician sediments. Tattam points out that outside this belt the Silurian sediments outcrop to the west, north, and east. These relations suggest either the elevation and erosion of the axis of Ordovician rocks around which the Silurian beds were deposited, or that it formed the major anticline of the whole Lower Palæozoic system in which both Silurian and Ordovician rocks were involved. He inclines to the latter point of view, i.e., that the period of folding and of intrusion of granites and gneisses followed the Silurian and is probably referable to the Lower Devonian period. The evidence is suggestive rather than conclusive, but I have adopted this view for the purposes of this paper.

Tattam has shown that many of the concordant granite gneisses, with NNW. strike of the foliation, are lit-par-lit injections into the Upper Ordovician sediments and include many examples of contaminated rocks. At Koetung the Tallangatta gneisses merge gradually into the massive acid granite. He regards the Tallangatta gneisses as a sheared phase of the granite. Howitt adopted the same view for most of the gneisses he examined further south near Omeo. At Corryong a grey granite is intruded by a pink granite and both of them by acid dykes. The Mitta Mitta and Bethanga gneisses and schists include acid granite dykes and veins which are tin-bearing. The acid granite of the Pilot range near Beechworth is also tin-bearing. The Buffalo granite is a true acid granite, while the Tatonga mass is granodiorite and the rock at Ensay is described as a quartz mica diorite. With the Lower Devonian granites may be placed tentatively, on inadequate evidence, the tin-bearing acid granite of Wilson's Promontory, the pink granite of Cape Wollamai and the porphyritic acid granites of the Dog Rocks and of the You Yangs, near Geelong. In this uncertain group just mentioned the granites in most cases can be proved to invade Ordovician rocks, but how much younger they are is uncertain.

NEW SOUTH WALES.

Browne (Pres. Addr. Linn. Soc. N.S.W., 1929) claims that the earth movements at the close of the Ordovician period were the most intense, except those closing the Willyama sedimentation, that have been experienced, not only in New South Wales, but also in Queensland, Victoria and Tasmania. He points out, however, that little igneous activity can be found to be associated with these earth movements in New South Wales. He instances the Cooma gneisses formed by lit-par-lit injection and with primary gneissic banding and with meridional strike of the foliation. The only other area referred to is Albury where schists are penetrated by acid granites. The evidence adduced by Dr. Browne seems to me to be insufficient to relate these intrusions to the close of the Ordovician period. In Victoria, as I have previously stated, post-Ordovician and pre-Silurian earth movements, while definite in some places, are in others feeble or absent, and the time interval, as measured by graptolite similarities in the two rocks, seems very small. We have no granitic rocks in Victoria which we can definitely assign to this period, unless we include on grounds of negative evidence the acid granites of Victoria which intrude Ordovician sediments but so far as is known do not come in contact with the Silurian. Dr. Summers (Proc. Roy. Soc. Vic., n.s., xxvi (2), 1914) showed, however, that study of the chemical analyses of the acid granites of Victoria links them with the granodiorites which invade the Silurian as well as the Ordovician sediments. The latter for reasons stated below are now placed in the Upper Devonian. Dr. Browne's evidence with regard to the Cooma gneisses shows that they are post-Ordovician, but he associates their intrusion with the earth movements at the close of the Ordovician without giving any definite evidence. In the circumstances, I think the balance of evidence, mainly indirect I admit, justifies me in placing these Cooma gneisses tentatively in the Lower Devonian and I would also include here the acid granites intrusive into the schists at Albury. The Kosciusko foliated gneiss and unfoliated acid granite and the composite mass with meridional trend stretching from Cooma northwards to the Federal Territory are also placed here. This intrusion is partly a quartz mica diorite, in places it becomes gneissic, especially on the eastern boundary and along this eastern edge is a pink or white acid granite-gneiss. Towards the northern end of the mass, orthoclase comes in and the rock becomes a granite with cataclastic foliation. Similar to the Kosciusko mass is an extensive intrusion of granite and gneiss from the Toolong and Bogong districts, 20-30 miles north of Kosciusko. East of the Federal Territory mass at Michelago are two elongated granitic intrusions with foliation in places. Further north on the eastern shores of Lake George a foliated granite-gneiss may belong to this period and at Wheeo, 60 miles north of Canberra, is a gneissic granite similar to the Cooma-Federal Territory mass.

QUEENSLAND.

The Charters Towers granodiorite with later aplite appears to belong to the Lower Devonian, for Middle Devonian sediments rest on it in places. Hence it is of pre-Middle Devonian age. At Silverwood in Southern Queensland, Richards and Bryan (Proc. Roy. Soc. Qld., xxxvi (6), p. 44, 1924) have described boulder beds including granite types which indicate the former existence in that district of granites of Lower Devonian or older age. Upper Devonian rocks in the Rockhampton district in Central Queensland contain granite pebbles and in the coastal strip between Rockhampton and Townsville granitic rocks of more than one age occur (Dr. Whitehouse, personal communication).

Upper Devonian.

TASMANIA.

The tin bearing granites of Tasmania in this discussion have been placed in the Lower Devonian, but it is recognized that this reference is not based on very positive information and there is a possibility that they may belong to the Upper Devonian or even to the Lower Carboniferous series of intrusions.

VICTORIA.

It has long been known that many of the granodiorites and adamellites of central Victoria are intrusive into but comagmatic with the dacite series. The dacites had been regarded as probably Lower Devonian, since in the northern part of the Strathbogie district there was some evidence that a rock apparently related to the dacite was overlain without intrusion by Upper Devonian or Lower Carboniferous sediments (Skeats, Pres. Add. Aust. Assoc. Adv. Sci. Brisbane, 1909). The recent work of Hills (Proc. Roy. Soc. Vic., n.s., xii (2), 1929, and xiii (1), 1929) has shown that in the Taggerty-Marysville district the Upper Devonian sequence consists of fossiliferous Upper Devonian sediments at the base, followed by rhyolites and then dacites. He has traced this succession to Marysville where the granitic rocks invade the dacites. It follows that these granodiorites and adamellites in central Victoria which are related in this way to the dacites, should now be referred to the close of the Devonian period. This includes granitic rocks in the Macedon, Dandenong ranges, Healesville, Warburton, Marysville and Strathbogie areas definitely. The Strathbogie granite continues westwards to Trawool. The remaining granitic rocks, apart from those previously referred to and with the exception of those in the Grampians to be discussed later, form a group whose age cannot be precisely defined. In the Werribee Gorge the adamellite was exposed before the Permo-Carboniferous tillites were laid down. Some of them, such as the Baw Baw, Gembrook, Narrewarren, Pyalong and Mount Disappointment masses, invade the Silurian sediments and are therefore post-Silurian. Others like the Harcourt masses and smaller intrusions in the Pyrenees are intrusive into Ordovician, generally Lower Ordovician, sediments but do not come into relation with younger rocks. They are principally granodiorites or adamellites and many of the goldfields of Victoria are in Ordovician rocks closely associated with these granitic rocks. All these rocks are here provisionally placed with the Upper Devonian as they have certain differences of distribution and of mineral characters from the Lower Devonian intrusions. In the Wedderburn district (O. A. L. Whitelaw, Mem. Geol. Surv. Vic. No. 10, 1911, pp. 9-10) an earlier coarse granite with porphyritic orthoclase is intruded by a later pink fine grained granite with tourmaline. These granites at the contact with the Ordovician sediments contain hornblende and pass into granodiorites. Both granites are invaded by felspar porphyrite and pegmatite dykes. In the extreme eastern part of Victoria a granite mass, starting at Gabo Island and Cape Everard passes northerly into south-eastern New South Wales where it is intrusive into Upper Devonian sediments. This granitic mass therefore is represented on the map as intrusive into the Upper Devonian.

NEW SOUTH WALES.

Under this age group appear to come the bulk of the granitic rocks of New South Wales except those previously referred to, and excepting also the younger granites within the Permo-Carboniferous basin in the eastern and north-eastern part of the State. Sussmilch has given the name of Kanimbla epoch to the period of earth movements and of granitic intrusions, which may possibly belong to or extend into the Lower Carboniferous. The intrusions consist of massive transgressive batholiths with a general meridional elongation which may be to some extent determined by the direction of Devonian folding. The distribution is generally within the limits of Upper Devonian strata, extending to beyond the River Darling to the west but not as far east as the Serpentine belt running through Tamworth. With these intrusions are associated gold, copper, silver, lead, zinc, and tin, tungsten and molybdenum, bismuth, and some antimony and arsenic deposits. These, with the exception of gold, are not found with the Older Palæozoic intrusions. It is true that these minerals are also characteristic of the late Palæozoic granites of New England, but these latter are geographically restricted to the north-east of New South Wales. Dr. Browne describes the principal masses, which include the following:—

Mt. Werong extending N.E. to Kanimbla and Hartley, and towards Jenolan and Bathurst and westerly through Sodwalls, Oberon and Tarana to Bathurst plains. Acid phases occur in the Upper Macquarie, and at Yetholme it has produced deposits of molybdenite and in other places gold and wolfram. It includes aplites, pegmatites, porphyritic biotite granite, hornblende biotite granite, quartz monzonite, granodiorite, quartz mica diorite, etc. Porphyritic granites outcrop between Capertee and Mudgee and non-porphyritic types N. of Mudgee, at Gulgong, Ulan in the Upper Goulburn Valley, and various places along the western margin of the Permo-Carboniferous basin as far as Wombeyan. At Blayney, Harper (1920) found sphene-bearing quartz mica-diorite resembling the Hartley type intrusive into old Palæozoic sediments and Morrison (1916) noted molybdenite in an acid granite at Manildra, near Molong. Near Dubbo is the northern extremity of a mass of granite which extends far to the south. At Yeoval in this belt tungsten occurs. At Engowra normal biotite granite rich in orthoclase occurs extending northwards towards Forbes and Parkes.

Morrison thinks this is intrusive into Upper Devonian strata and petrological characters support this, but Andrews (1910) says it is pre-Devonian. Possibly there are two intrusions of different ages. The biotite granite of Cowra contains occasional garnets derived from sediments. This is probably Upper Devonian. The granites in the Condobolin district and Nymagee and Nuyngan are all believed to be Devonian. At Wyalong (Watt, 1899) quartz mica diorite, much crushed in places, passes into hornblende quartz diorite with fluxional fabric. At Ardlethan Harper (1912) described some biotite granite, but the principal type is very acid with tourmaline, topaz, mica and fluorspar; metallic minerals are ores of tin, copper, bismuth, molybdenum, tungsten, lead and zinc. The acid phase extends 45 miles NNW. through Yalgogvin to Mulyan and at least 30 miles SE. of Ardlethan and it may be more than coincidence that ores of tin, tungsten and molybdenum, associated with acid granite are found at intervals along a belt running SSE. through Pulletop, Holbrook to Jingellic on the Murray (Carne 1894; Harper 1912). At Hume reservoir, 10 miles from Albury, a granite of the massive biotite type is different petrologically, and is grouped by Dr. Browne with the Kanimbla types. I personally prefer to associate it with the Lower Devonian(?) intrusives in N.E. Victoria. At Adelong Harper (1916) states that quartz felspar porphyry accompanies the granite, which is partly a hornblende-biotite type but with acid differentiates, greisen, aplite and tourmaline rocks. This Adelong granite may belong to the same mass as that of Tumbarumba to the south and a porphyritic granite north of Yarrangobilly. The eastern margin of what is believed to be the same granite crosses the Murrumbidgee at

Burrinjuck, intruding into Middle Devonian sediments, and is a granite with both normal and pink acid varieties. At Kiandra, Andrews (1901) includes monzonites, also biotite hornblende granite with sphene, closely resembling some of the Bathurst-Hartley types, but the relations to the monzonite are uncertain. At Berridale, the granite extends north towards Adaminaby and south through Dalgety. It is tonalitic between Berridale and Cooma, is massive and post-Ordovician and believed to be late Devonian from its petrological and structural characters which contrast strongly with the intrusions of Cooma. The similar granodiorite of Gunning and quartz diorite of Binalong (Carne 1892) are believed to be late Devonian. The Tallong hypersthene-diorite (Woolnough 1909), is associated with the Marulan granite. South from Goulburn are the massive acid granites of Mt. Fairy and Boro, south-east of Tarago, where tinstone has been mined (Harper 1915). At Braidwood and Major's Creek occurs a hornblende biotite granite with free gold. At Yalwal the section in the Shoalhaven tributaries shows Upper Devonian sediments injected by acid granite. At Moruya, on the South coast (Browne 1928), is a complex ranging from ultra-acid aplite to basic hornblende gabbro. The intrusion is sheet-like and may link up with that of Araluen about 30 miles north-west. Further south along the coast are quartz diorites at Cobargo, probably of Kanimbla age, the granite and quartz mica diorite of Brogo, and porphyritic granite and sphene bearing granodiorite of Bega. This complex extends west nearly to Nimmitabel, south-west to near Bombala and south through Wolumla and Wyndham beyond the Victorian border east of Nungatta River; gold, tungsten, molybdenum and bismuth occur in it (Carne 1897).

Among the Kanimbla intrusions there is a tendency for the concentration of tinstone along the western or south-western part of the area and of sphene in granites and granodiorites of the more easterly belts, such as the south coast and along the western margin of the Permo-Carboniferous basin. Carne (1896) has shown on the South Coast at Eden and Pambula and possibly Wagonga and Tathra further north that auriferous quartz felsites intrusive into Upper Devonian sediments are themselves intruded or metamorphosed by the granite. It appears that the felsites antedate the granites while porphyries and porphyrites were sometimes later than the granites but frequently of indeterminate age relationship. Kanimbla intrusions are cut off sharply to the east by the western boundary of the Permo-Carboniferous basin, but the granodiorites of Pokolbin (David 1907) and Gosforth (Browne 1926), exposed by faulting and erosion, are sphene-bearing rocks of Kanimbla type and are overlain by Kuttung sediments and lavas.

One difficulty experienced in setting down on a map of Eastern Australia the granitic areas and trying to represent intrusions of different ages by different shading, is the lack of respect shown by granitic masses in ignoring interstate boundaries. The Kosciusko mass starts in North-Eastern Victoria and extends as a continuous mass in a northerly direction past Young to Grenfell. On the Victorian side these are shaded as Lower Devonian(?) intrusions and the author has continued the shading into New South Wales in the Kosciusko mass until he lost courage as he was trespassing into the heart of the Upper Devonian intrusions.

Some of the difficulty may be due to the fact that the Geological Survey maps in this part of Victoria and of New South Wales represent only reconnaissance work and intrusive masses shown as continuous may be really discontinuous. It may be that a continuous intrusion may be a composite of intrusions of different ages. Certain it is that we have still much to learn before we can set down on a map information as to age and distribution of the granites in this region which is beyond the reach of destructive criticism.

QUEENSLAND.

The granite of Newelltown in North Queensland may be Upper Devonian or even possibly Lower Carboniferous. Jensen (Qld. Geol. Surv., Publ. 274, 1923, p. 19) quotes Stirling as stating that the granitic intrusions do not affect sediments containing Rhacopteris. The granite may be Upper Devonian but the intrusion of similar granites into the Hodgkinson series (Devonian) according to Jensen makes it likely that the granites are Devono-Carboniferous or early Carboniferous.

Carboniferous.

TASMANIA.

Granites definitely of this age are unknown in Tasmania. It is just possible that the tin-bearing granites, or some of them, may belong here.

VICTORIA.

The Grampian sandstones in Western Victoria yielded a few fossils some years ago (Ferguson, Chapman, Rec. Geol. Surv. Vic., v (1), 1917). The fish remains include *Physonemus micracanthus* Chapman, and *P. alternatus* Davis. In addition the brachiopod *Lingula squamiformis* Phillips, var. *borungensis* Chapman occurs in considerable numbers in a very thin band of shale. On this evidence Mr. Chapman says they undoubtedly belong to the Lower Carboniferous. Professor Benson, however, (Trans. N.Z. Inst., 1923, p. 28) is not convinced that these few fossils finally settle the Lower Carboniferous age of the Grampian sandstone. He points out that *Lingula squamiformis* also occurs in the Upper Devonian and the evidence from the fossil fish is not convincing. He is inclined to group them with the Upper Devonian. I have followed Mr. Chapman in his interpretation, but I realize that if Professor Benson is correct these rocks would find a place with the Upper Devonian of this State. Granitic rocks of the hornblende granodiorite type, and hornblende porphyrite and quartz porphyrite dykes, are all intrusive into the Grampian sandstone at Mt. William and also near Wartook dam (Skeats, E. W., Proc. Roy. Soc. Vic., n.s., xxxvi, 1923). I have suggested that the intrusions may have occurred during the formation of the main geosyncline of the Grampians possibly during the Middle to Upper Carboniferous periods. If, however, these sandstones belong to the Upper Devonian, the intrusions may fall into line with the Upper Devonian intrusions of Central Victoria.

New South Wales.

No granitic intrusions can with certainty be placed here, but it is possible that some of the earlier of the New England granites may belong to this period. Near Ashford, Sir Edgeworth David has recently (May, 1930) found a small granite erratic in Permo-Carboniferous fluvio-glacial conglomerate and what appears to be a similar granite in situ within half a mile. G. D. Osborne's evidence of absence of granite pebbles in massive Wallarobba conglomerates at the base of the Kuttung, but extraordinarily abundant coarse shingle and blocks of granite on top of the volcanic series of the Kuttung, i.e., top of the Middle Kuttung (200 feet thick coarse conglomerate entirely formed of granite), indicate the former exposure of granites of at least Carboniferous age.

Queensland.

No granitic rocks of this age are definitely known. It is possible that the Newellton granite, described under the Upper Devonian, may belong here.

Permo-Carboniferous.

Tasmania and Victoria.

No granitic rocks of this age are known.

New South Wales.

Granitic rocks of this age appear to be restricted to the New England district and were first clearly described by Andrews (Rec. Geol. Surv. N.S.W., viii (3), 1905), who states that the youngest of them may belong to the commencement of the Mesozoic period.

The sequence established by Andrews is:—

1. "Blue granite," a sill or laccolithic intrusion of quartz porphyrite with augite, hornblende and biotite phenocrysts set in a fine-grained to microcrystalline matrix.
2. Quartz monzonite or granodiorite with large crystals of sphene and orthoclase. This rock is of great areal extent throughout northern New England and a similar type occurs at Kootingal and Walcha Road about 150 miles to the south.
3. Coarse acid granites with aplite, quartz porphyry and spherulitic granophyre dykes. These granites are associated with the deposits of tin, molybdenum, bismuth, tungsten and antimony so widespread in northern New England.

At Mount Dromedary, on the south coast of New South Wales, Miss Brown (Proc. Linn. Soc. N.S.W., liv (1), 1929) described the injection of a monzonite magma with alkaline differentiates including shonkinites and nepheline-bearing types. It is the only alkaline plutonic intrusion of probable pre-Triassic age in New South Wales.

QUEENSLAND.

Jensen (Qld. Geogr. Journ., 1918-20) described the early Carboniferous as a time of violent folding and great granitic intrusion in northern Queensland, but in a later publication (Qld. Geol. Surv. Publ. No. 274) he says the "Newer granites of the Etheridge and Croydon districts have not undergone metamorphism. They are consequently of Carboniferous or later age. . . . probably late Carboniferous." Ball regards most of the granites of North Queensland as of Permian age. Bryan (Pres. Addr. Roy. Soc. Qld., 1925) agrees with the Permian or Permo-Carboniferous age of these granites and extends it also to those of Southern Queensland with a few exceptions to be noted later. Among these granites are the newer intrusions of the following districts: Herberton, a biotite granite; Etheridge, a hornblende and biotite granite; Chillagoe, including tonalite and monzonite; Cairns, Mareeba and Townsville, true granites. All these are in North Queensland. Among the South Queensland granitic intrusions also placed here are the intrusions of Enoggera and Kedron Brook near Brisbane, with granite porphyry, hornblende quartz diorite and biotite granite. The Silverwood granite and the Maryland adamellite are placed here. True granites occur near the New South Wales border in the Stanthorpe district, while the "Blue granite" of Wallangarra is a granite porphyry.

Triassic and post-Triassic.

TASMANIA AND VICTORIA.

No granites of Triassic age are known.

NEW SOUTH WALES.

Andrews (1905) suggested the possibility that some of the later granites of New England might belong to the earliest part of the Mesozoic period. This view has been confirmed and made precise by recent evidence obtained by Professor Richards and Drs. Bryan and Whitehouse (personal communication, May 4th, 1930). They have shown in the Drake goldfield at Kettle's Lift, between Drake and Tabulam and about 6-7 miles west of Tabulam, that the Clarence series, containing *Cladophlebis*, and probably of Walloon age, is disturbed and intruded by a granite resembling the "Sandy granite" near Wallangarra.

This is the first definite record in New South Wales of granites intruding rocks probably of Upper Triassic age.

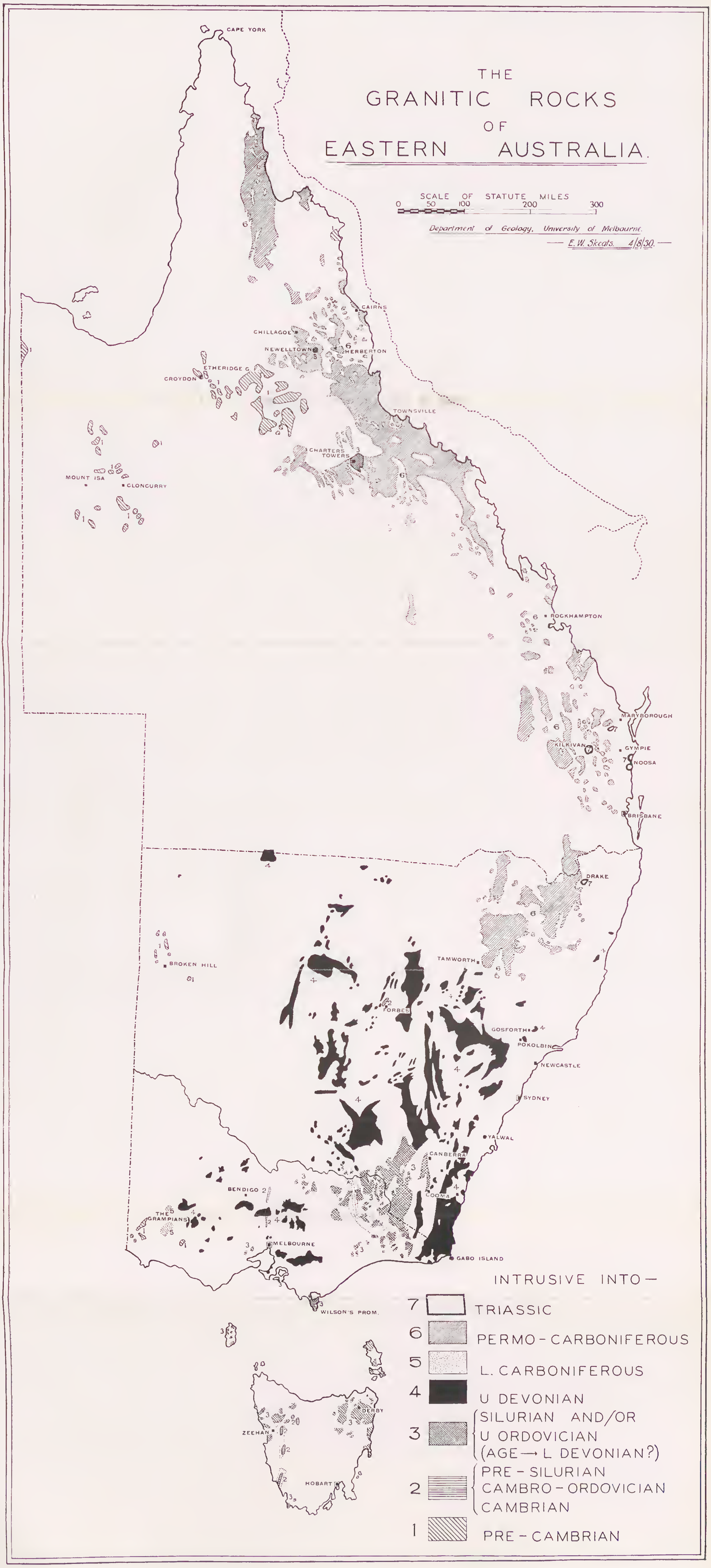
QUEENSLAND.

The youngest granitic rocks of Queensland, so far as is yet known, occur in the most easterly part of Queensland in the neighbourhood of Gympie and of Maryborough. At Mt. Bopple, south-west of Maryborough, graphite has been formed by intrusions of "syenite" (Min. Index of Qld., p. 761) into the Tiaro series (Walloon). At Kilkivan, 30 miles north-west of Gympie, the presence of a cinnabar lode in tuffaceous rocks yielding *Cladophlebis* and also in a neighbouring granite suggests a granitic intrusion into the Upper Triassic sediments. At Point Arkwright and Noosa, south-east of Gympie, grey diorite intrusions into the Tiaro (Walloon) coal measures occur. These occurrences appear to be the youngest granitic intrusions in Queensland of which there is evidence.

Possible Generalizations.

A survey of the evidence of the granitic intrusions of Eastern Australia indicates certain possible correlations or generalizations which may be suggestive. Among them are such questions as:

1. The areal distribution of the granitic intrusions.
2. The association of granitic intrusions with periods of severe mountain folding.
3. The association of granitic intrusions with directions of fold or fault movements.
4. The association of particular geological periods with soda-rich intrusives.
5. The relation of certain granitic intrusions to the occurrence of metallic minerals.


THE
GRANITIC ROCKS
OF
EASTERN AUSTRALIA.
SCALE OF STATUTE MILES
0
50
100
200
300
Department of Geology, University of Melbourne.
E. W. Skeats. 4/8/30.
CAPE YORK
CAIRNS
CHILLAGOE
NEWELLTOWN
HERBERTON
ETHERIDGE G.
CROYDON
TOWNSVILLE
CHARTERS TOWERS
MOUNT ISA
CLONCURRY
ROCKHAMPTON
MARYBOROUGH
KILKIVAN
GYMPIE
NOOSA
BRISBANE
DRAKE
BROKEN HILL
TAMWORTH
FORBES
GOSFORTH
POKOLBIN
NEWCASTLE
SYDNEY
YALWAL
CANBERRA
COOMA
GABO ISLAND
BENDIGO
THE GRAMPIANS
MELBOURNE
WILSON'S PROM.
DERBY
ZEEHAN
HOBART
INTRUSIVE INTO—
7 TRIASSIC
6 PERMO-CARBONIFEROUS
5 L. CARBONIFEROUS
4 U DEVONIAN
3 SILURIAN AND/OR U ORDOVICIAN (AGE → L DEVONIAN?)
2 PRE-SILURIAN CAMBRO-ORDOVICIAN CAMBRIAN
1 PRE-CAMBRIAN

l

la
o
p
D
19
L
o
ar
g

in

k
ne
so
tr
Ti
G
yi
a
A
si
oc
Q

A
w

THE AREAL DISTRIBUTION OF GRANITIC INTRUSIONS.

1. The Pre-Cambrian granites appear to be limited to the western part of Eastern Australia, i.e., Western Victoria, Western New South Wales and the Western part of North Queensland. This may lend support to the hypothesis of the growth of Australia from West to East by the attachment of folded sedimentary geosynclines on the eastern border of the continent throughout the Palæozoic and Mesozoic periods. These later accretions apparently have not been sufficiently deeply dissected by erosion to expose any Pre-Cambrian rocks in the Eastern part of Eastern Australia. At Facing Island, however, ancient schists are unconformably overlain by a representative of part of the Brisbane schist series.

2. Cambrian and Cambro-Ordovician intrusions are limited to small areas in Western Tasmania and in Central Victoria with the possible inclusion of a small area of soda-rich intrusions in the Ordovician of the Forbes District of New South Wales.

3. Lower Devonian(?) granitic intrusions are widespread in Tasmania, Eastern Victoria and in Southern New South Wales. There is some uncertainty as to the precise age of the Tasmanian intrusions and of some of those in Victoria and New South Wales.

4. Upper Devonian granitic intrusions are spread widely in Central Victoria, and in New South Wales occur in the southern, south-eastern and west-central parts.

5. Lower Carboniferous intrusions are recorded in a small area in the Grampians in Western Victoria and at Newellton in North Queensland. These may possibly be Upper Devonian in age.

6. Permo-Carboniferous intrusions are not recorded in Tasmania and Victoria. In New South Wales they are restricted to the north-east part of the State but are widely distributed in Queensland, in the south, the central and the northern parts of the State.

7. Triassic or post-Triassic intrusions have recently been recognized near Drake in Northern New South Wales and at three localities in South-Eastern Queensland, near Gympie and Maryborough.

This distribution suggests an easterly migration of the locus of granitic intrusion from the Pre-Cambrian up to and including the Lower Devonian period, the latest period of severe compressive movements in the southern part of Australia.

In the Permo-Carboniferous the area is restricted to Eastern and Northern Australia.

In the Triassic or post-Triassic the intrusions are still more narrowly restricted to limited areas in Northern New South Wales and South-East Queensland.